

C.R. Chappell
ESSI

N84-25205

QUARTERLY PROGRESS REPORT

Contract NAS8-33982

PLASMA AND MAGNETOSPHERIC RESEARCH

December 1983 - February 1984

by

Richard H. Comfort

and

James L. Horwitz

Prepared for

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

Marshall Space Flight Center, Alabama 35812

Submitted by

The University of Alabama in Huntsville

School of Mathematical and Natural Sciences

Huntsville, Alabama 35899

March 1984

ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

During this period, the program which converts DE/RIMS RPA data into distribution functions (RIMSDF) has been improved and extended. This technique is desirable for analyzing charging phenomena, plasmas characterized by multiple temperatures, and other non-Maxwellian plasmas. By using the distribution function constructed from the measurements and calculating the moments, it is possible to characterize such plasmas in terms of a density and average energy. This method will be applied to the warm, equatorially trapped plasmas frequently encountered by DE 1.

An instrumental artifact has been noted with this analysis technique. For the ram direction the distribution function method provided plasma parameters in agreement with those obtained by the thin sheath analysis of the RPA curves from the radial head. This comparison was carried out in the plasmasphere at a density of about 1000 cm^{-3} , with temperatures of 0.4 to 0.5 eV. However, when end head data were analyzed, it appeared that there was a colder population, as suggested by a sharp rise in the ion distribution function below 1 eV. A fit to the 0-1 eV portion of the distribution function indicated a temperature of ~ 0.1 eV. Radial detector data taken 90° from the ram direction showed a similar effect. This also appears to correspond to the deviation of the thin sheath model from the end head RPA data, noted in the previous report. Although it seems plausible that this might be a sheath effect, analysis of eclipse data has demonstrated that this phenomenon is independent of spacecraft potential. This reduces the likelihood that this results from a sheath problem.

One interpretation of this phenomenon is that it results from an increase in detector efficiency by about a factor of 5 for energies below 1 eV, due to stray electric fields within the entrance aperture region. An

empirical "fudge factor" has been developed and incorporated into the distribution function analysis to remove this effect, until a clear understanding of the problem can be used to develop an adequate quantitative model to compensate for it.

Another area of significant development involves techniques for spin curve analysis. Previously, Mike Chandler had generated a "catalog" of spin curves from the SHEATH program for a broad range of values of Mach number and spacecraft potential. By empirically testing a number of mathematical models, we have determined one which represents the parametric dependence of the spin curves on these two variables within 3% over the range covered. This empirical, analytical model has been incorporated into a computer subroutine, SPNMOD, for ready numerical evaluation of spin modulated data. Another subroutine, TSPIN, has been developed which uses TSHETH for normalization and SPNMOD for spin modulation. The TSPIN routine has been incorporated into MSSPEC, the program which generates theoretical spin curves for comparison with RIMS observed spin curves. This software is now available for use in calibration and analysis studies and for the further development of analysis techniques.

Development of methods for performing spin analysis on PWI Step Frequency Receiver data is nearing completion. This effort is a vital link in the identification of observed wave emissions. One of the first applications will be to look for plasma noise generated in the DE 1 wake.

While developing this procedure, we also discovered a small error in the interpretation of the spin phase angle of the RIMS data with respect to the observed magnetic field. Since the error is of the order of one degree, it is significant only to those RIMS studies which attempt to obtain that order of angular resolution. One such study is that being

carried out by Mike Chandler, who is trying to resolve small field-aligned flows of thermal ions in the plasmasphere.

We have continued to participate in efforts to obtain a Local Area Network (LAN) for the Space Science Laboratory (SSL). Since that process has been incorporated into the Class VI procurement, we have worked closely with SSL personnel to produce wording in the Class VI RFP which will result in the purchase of the best LAN for SSL. Dr. Gallagher is now serving as a member of the SSL Computer Committee. Work has also started on the SCAN workstation, most of the hardware and software having been received. All these developments portend significant changes in the methods for carrying out data analysis in SSL in the near future.

During this period, we completed installation at UAH of a computer terminal which is connected to the SCAN central mode via a MSFC supplied dedicated data line. This terminal is capable of displaying Tektronics 4010/4014 graphics and, with a compatible printer, could reproduce both text and graphics. It will greatly facilitate the use of the SCAN central node and the SSL Magnetosphere Branch PDP 11/34 computer by UAH researchers who must be at the University for other reasons.

A computer program to aid in the analysis of data acquired by the Differential Ion Flux Probe (DIFP) on the STS-3 mission (March, 1982) has been completed. This program generates a plot of the space shuttle silhouette in any desired coordinate plane. For a given plane, several vector projections and their variations over a one minute interval are displayed: (1) the relative motion between the instrument and the shuttle; (2) the instrument normal and tangent; (3) the plasma ram velocity; (4) and the ambient magnetic field direction (the latter two assumed constant over the interval). Use of these plots is essential in analyzing the observed

secondary (non-ram) ion streams. Preliminary indications are that these secondary streams are correlated with the magnetic field direction and that an interaction boundary may exist in front of the shuttle.

SATELLITE DATA ANALYSIS

Analysis of conical ion distributions between 1 and 10 thousand kilometers altitude near the plasma sheet boundary has revealed 90 degree pitch angle distributions and enhanced temperatures which are indications of ion heating in the measurement region. DE/RIMS is apparently making the first *in situ* measurements of ion acceleration in the topside ionosphere. We find that hydrogen, helium, nitrogen, and singly and doubly charged oxygen all participate in this process. Since pitch angle distributions peaked at 90 degrees generally appear in only one mass species, it appears that the heating of different ions occurs at different altitudes.

The study of high densities and plasma flows in the polar cap has made considerable progress. HAPI observes 20 kms^{-1} field-aligned flows and transverse drifts of similar magnitude during a day 287, 1981 traversal of the polar cap. Densities derived from PWI observations are found to be about 50 cm^{-3} . Both RIMS and HAPI also suggest high densities. RIMS observations of low energy ($<5\text{eV}$) H^+ and He^+ indicate anti-sunward convection at $\lesssim 5 \text{ km s}^{-1}$. These results will be presented to the Spring AGU Meeting (Ref. 1).

Extensive effort was devoted to a detailed analysis of polar wind observations on Day 287, 1981 for T. Nagai's study. The important geophysical result was the first demonstration that an observed "classical" polar wind flow was clearly supersonic. Much was also learned about techniques for using aperture bias observations in conjunction with the

unbiased data, when this is possible. An interesting side result was the determination that the data set analyzed had the characteristics of data taken with an "open aperture" (90° half angle) RPA. This apparently resulted from the integration over spin angle in assembling the data set or because the distribution was sufficiently folded toward the field line that all available flux entered the aperture. Future polar wind studies should keep this latter possibility in mind in analyzing the data. This work has been submitted for publication in GRL (Ref. 2).

Activity has also continued on Hunter Waite's PC-5 study. Detailed quantitative analysis has been carried out to determine density, temperature, and composition. Ambiguities associated with positive spacecraft potentials have been difficult to resolve since other conditions, not necessarily associated with the PC-5 event, appear to be changing along the DE 1 orbit. The additional time taken for this extensive analysis has also permitted a more thorough literature search, which will result in an improved study. The paper documenting this study is in a revised draft stage and will be submitted to JGR for publication in the next reporting period (Ref. 3).

We have provided density and temperature profiles for several plasmasphere transits to Larry Brace (GSFC) for comparison with his Langmuir probe measurement on DE 2. These comparisons show a good correlation between a topside ionosphere electron temperature enhancement and the location (in invariant latitude) of the plasmapause density and temperature gradients identified by RIMS. It appears that heating processes causing the enhanced ion temperature gradient near the plasmapause at high altitudes are also heating the electrons, followed by

thermal conduction down the field lines to the ionosphere. It remains to be determined how prevalent this signature is.

LABORATORY PLASMA FLOW STUDIES

Data from the laboratory plasma flow interaction with a "semi-infinite" plate experiment has been completed. The objective of the experiment was to verify experimentally the existence of phenomena occurring in the wake region associated with "plasma expansion into a vacuum" theory. The characteristics of the data, specifically the rarefaction wave, expansion front motion, ion velocity field, and ion velocity behavior at the expansion front position, are all consistent with the plasma expansion process. These results demonstrate the operation of this process in the wake region of the plasma flow/body interaction. Preliminary results were presented to the 1984 Yosemite meeting (Ref. 4), and a draft of a paper containing detailed results is in preparation for submission to JGR (Ref. 5).

PUBLICATIONS AND PRESENTATION

In addition to those noted above, the following papers are at the indicated stage of the publication cycle.

Papers published were those on ionosphere-plasmasphere plasma interchange (Ref. 6), multiple ion streams near the space shuttle (Ref. 7), MHD model of whistler duct structure (Ref. 8) and four papers in the proceedings of the Spacecraft/Plasma Interactions meeting (Ref. 9-12). Papers accepted and in press include those on: electron energy dispersion at the inner plasma sheet (Ref. 13), plasmaspheric He^+ in diffusive equilibrium (Ref. 14) and magnetospheric plasma dynamics (Ref. 15).

Submitted and under review are the paper on equatorial plasma heating (Ref. 16) and an article on the plasmapause conference (Ref. 17). The paper on electrostatic waves in the magnetosphere (Ref. 18) has undergone such extensive revision that it will be resubmitted. Abstracts for papers on the following topics have also been submitted for presentation to the Spring AGU Meeting: electron energy dispersion (Ref. 19), more hidden ions (Ref. 20), radial electric field measurements (Ref. 21), and GEOS/DE1 comparisons of the bulge region (Ref. 22).

Richard H. Comfort

R. H. Comfort

J. L. Horwitz

J. L. Horwitz

REFERENCES

1. Gallagher, D. L., J. D. Menietti, A. M. Persoon, J. H. Waite, Jr., and C. R. Chappell, Evidence of high densities and ion outflows in the polar cap during the recovery phase, to be presented to the Spring Meeting of the American Geophysical Union, Cincinnati, OH, May 14-18, 1984.
2. Nagai, T., J. H. Waite, Jr., J. L. Green, C. R. Chappell, R. C. Olsen, and R. H. Comfort, First measurements of supersonic polar wind in the polar magnetosphere, submitted to Geophys. Res. Letters, 1984.
3. Waite, Jr., J. G., J. F. E. Johnson, C. R. Chappell, D. L. Gallagher, R. C. Olsen, R. H. Comfort, D. Weimer, S. D. Shawhan, W. K. Peterson, and E. G. Shelly, Observations of a PC-5 wave event on 1982 Day 195 by particle and wave instruments on the DE 1 spacecraft, to be submitted to J. Geophys. Res., 1984.
4. Stone, N. H., U. Samir, and K. H. Wright, The plasma expansion phenomenon: Its characteristics, experimental observations and possible application to the environmental dynamics of celestial bodies, presented to the 1984 Yosemite Conference on the Planetary Plasma Environment: A Comparative View, Yosemite, CA, January 28-February 3, 1984.
5. Wright, K. H., N. H. Stone, and U. Samir, The wake of the semi-infinite plasma - the plasma expansion phenomenon, to be submitted to J. Geophys. Res..
6. Horwitz, J. L., Major questions on the interchange of the thermal plasmas between the ionosphere and the plasmasphere, J. Atmosph. Terr. Phys., 45, 765, 1983.

7. Stone, N. H., U. Samir, K. H. Wright, Jr., D. L. Reasoner, and S. D. Shawhan, Multiple ion streams in the near vicinity of the Space shuttle, Geophys. Res. Lett., 10, 1215, 1983.
8. Wang, S., J. F. Wang, and R. H. Comfort, A magnetohydrodynamic model of whistler duct structure in the magnetosphere, Planet Space Sci., 32, 143, 1984.
9. Olsen, R. C., C. R. Chappell, D. L. Gallagher, J. L. Green, and S. D. Shawhan, Potential control methods for thermal plasma measurements on the DE-1 satellite, proceedings of the 17th ESLAB Symposium on Spacecraft-plasma Interactions and their Influence on Field and Particle Measurements, September 13-16, 1983, Noodwijk, Netherlands, p. 177.
10. Olsen, R. C., P. M. E. Decreau, G. L. Wrenn, J. F. E. Johnson, A. Pedersen, and K. Knott, A comparison of thermal plasma observations on SCATHA and GEOS, proceedings of the 17th ESLAB Symposium on Spacecraft-plasma Interactions and their Influence on Field and Particle Measurements, September 13-16, 1983, Noodwijk, Netherlands, p. 57.
11. Pedersen, A., C. R. Chappell, K. Knott, and R. C. Olsen, Methods for keeping a conductive spacecraft near the plasma potential, proceedings of the 17th ESLAB Symposium on Spacecraft-plasma Interactions and their Influence on Field and Particle Measurements, September 13-16, 1983, Noodwijk, Netherlands, p. 185.

12. Whipple, E. C., R. C. Olsen, I. Krinsky, and R. Torbert, Anomalously high potentials observed on ISEE-1 in sunlight, proceedings of the 17th ESLAB Symposium on Spacecraft-plasma Interactions and their Influence on Field and Particle Measurements, September 13-16, 1983, Noodwijk, Netherlands, p. 35.
13. Horwitz, J. L., Relationship of a dusk-sector electric field to electron energy dispersion at the inner plasma sheet, in press, J. Geophys. Res., 1984.
14. Waite, Jr., J. H., J. L. Horwitz, and R. H. Comfort, Diffusive equilibrium distributions of He^+ in the plasmasphere, in press, Planet. Space Sci., 1984.
15. Horwitz, J. L., Dynamics of magnetospheric plasmas, to be published in AIAA book on spacecraft charging, ed. by A. L. Vampola, 1984.
16. Olsen, R. C., S. D. Shawhan, D. L. Gallagher, J. L. Green, and C. R. Chappell, Observations of plasma heating at the Earth's magnetic equator, submitted to J. Geophys. Res., 1983.
17. Horwitz, J. L. and J. L. Green, Fundamental magnetospheric processes in the plasmapause region, submitted for publication in EOS, Transactions of the American Geophysical Union, 1984.
18. Gallagher, D. L., Electrostatic waves in the Earth's magnetosheath, to be resubmitted to J. Geophys. Res., 1984.
19. Horwitz, J. L., A simple formula relating the dusk sector radial electric field to electron energy dispersion at the inner edge of the plasma sheet, to be presented to the Spring Meeting of the American Geophysical Union, Cincinnati, OH, May 14-18, 1984.

20. Olsen, C. R., D. L. Gallagher, C. R. Chappell, J. L. Green, and S. D. Shawhan, The hidden ion population - revisited, to be presented to the Spring Meeting of the American Geophysical Union, Cincinnati, OH, May 14-18, 1984.
21. Ledley, B. G., T. L. Aggson, and R. C. Olsen, Radial electric field measurements near the midnight plasmapause, to be presented to the Spring Meeting of the American Geophysical Union, Cincinnati, OH, May 14-18, 1984.
22. Decreau, R. M. E., C. R. Chappell, J. L. Green, J. H. Waite, Jr., D. Gurnett, R. H. Comfort, R. C. Olsen, and A. Pedersen, A three-dimensional view of the plasmaspheric bulge: GEOS-2/DE-1 comparisons, to be presented to the Spring Meeting of the American Geophysical Union, Cincinnati, OH, May 14-18, 1984.